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A FROZEN-SPIN POLARIZED PROTON TARGET FOR USE AT LAMPF^{*}

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Abstract

A frozen spin polarized proton target has been developed and used at LAMPF to measure the spin correlation parameter A_{SS} for proton-proton elastic scattering. The target consisted of a horizontal dilution refrigerator, superconducting magnet, plus other equipment. The target refrigerator was fixed and the magnet moved on a rail system. The design permitted the same magnet to be used for both the polarizing and holding functions. In the holding configuration the magnetic field at the target was about 0.3 T, and the open angular region for detecting scattered particles was 0° to 90° lab. With ethylene glycol target material a typical holding time of 500 h was observed.

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I. Introduction

The motivation for the design of the present target was the desire to measure the spin correlation parameter A_{SS} for proton-proton elastic scattering (LAMPF Proposal E-512). For this experiment both the incident proton beam and target must be polarized with their respective polarization vectors transverse to the incident beam momentum and in the horizontal plane. For the detection of the elastic p-p scattering events an open angular access from 0° to 90° laboratory was desired. It was not possible to provide this angular access with a conventional polarized target that used liquid helium three cooling and continuously polarizes the target in a magnetic field of 2.5 T. For an S-type conventional target the angular range from about 7° to 45° lab was obstructed by the magnet coils. The solution to the problem was the utilization of the frozen spin technique developed at the Rutherford and CERN laboratories.^{1,2} With this method the target is polarized at a field of 2.5 T and a temperature near 0.4 K by applying microwave power. After polarizing, the microwaves are turned off and the target temperature reduced to less than 0.05 K by $^3\text{He}/^4\text{He}$ dilution cooling. At this low temperature the proton spin lattice relaxation time is long even at reduced magnetic field.² With a suitably designed system either the target cryostat or magnet can be moved to position the target cell in a region of reduced field with larger angular access. For the present experiment the magnet was moved and the target refrigerator held fixed. This approach was feasible because of the relatively low weight of the magnet (about 2,000 lbs.). It offered the advantage that once the target cell was aligned on beam line it remained fixed, thereby simplifying beam tuning.

II. Frozen Spin System

A schematic layout of the frozen spin target is shown in Fig. 1. The polarizing/holding magnet was a superconducting split coil solenoid in the Helmholtz configuration obtained from the CEN Laboratory at Saclay, France.³ The magnet was mounted on a rail system and moved by a motor driven worm gear. A nonmagnetic 1,000 liter dewar was also mounted on a rail system next to the magnet. Liquid helium was continuously transferred through a one meter long rigid transfer line. Other connections to the magnet were made to accommodate the movement. In the polarizing position the target was at the center of the magnet. Here the field was 2.5 T with a field variation of less than 10 G over the target cell. After polarizing, the field was reduced to about 1.25 T and the magnet moved to the holding position. This positioned the target cell 0.6 m from the magnet center in a field of about 0.3 T. The field gradient was 160 G/cm parallel to the field. The holding position provided angular access from 0° to 90° lab for detecting p-p elastic scattering. The horizontal dilution cryostat was developed at ANL. It was originally designed for ³He cooling, but then modified by SHE Corporation of San Diego, California for dilution cooling. The modification consisted of adding a still, sintered heat exchanger, and mixing chamber. The cryostat was capable of polarizing a 1.6 x 1.6 x 5 cm³ target (about 2/3 filling factor) of ethylene glycol target material, at a refrigerant temperature of approximately 0.4 K, to a peak polarization of ± 90%. The peak ³He circulation rate (~ 10% ⁴He) was 7 mmole/s with a still power of 125 mW. In the spin frozen mode the ³He circulation was reduced to 1.6 mmole/s with a still power of 55mW. Refrigerant temperature was measured with a calibrated Ge resistor.

III. System Performance

The target material was ethylene glycol mixed with potassium dichromate to provide approximately 6×10^{19} spins/cm³. The material was in the form of frozen spheres of 1.8 mm diameter. The measured relaxation time at 1 K was 15 min. Polarization reversal time was 75 min (+ 80% to - 80%). The total time required to reverse polarization was two hours. The sequence was to move the magnet from holding to polarizing position, increase the field to 2.5 T, measure and reverse polarization, lower the target temperature, reduce the field and then move the magnet to the holding position. In the spin frozen mode the refrigerant temperature was ≤ 25 mK. With a 0.8 GeV/c proton beam intensity of $\sim 1 \times 10^5$ protons/cm²/sec, a polarization holding time of 500 hr was typical.

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